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IMPROVING THE QUALITY OF STAPLE FOODS

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IMPROVING THE QUALITY OF STAPLE FOODS

By GEORGE R. COWGILL, Ph.D., Sc.D. *(Guest Editor)**

The science of nutrition has developed in recent years to the point where one can now state much more exactly what specific substances man and various animals must eat in order to be properly nourished. Many of the vitamins are now being manufactured in huge amounts and made available at relatively low cost, and their addition to foods is economically feasible. Enriched wheat flour is a good example of a food used on a large scale to which several dietary essentials are now added at an insignificant increase in cost. It is natural that nutritionists, clinicians, students of public health and governmental agencies, as well as the food industry, should interest themselves in the formulation of principles to be followed when making such additions to food so that the maximum of benefits for public health are achieved with a minimum of cost and undesirable effects of one kind or another.

In any discussion of the nutritional improvement of foods, it is well to distinguish between several categories of interest: (a) the staple foods, those which are used by the general population in relatively large amounts, *e.g.,* cereals; (b) valuable foods which, for one reason or another (taste, texture and related "acceptance" factors), are not now used by the general population to the extent that their nutritional value would seem to justify; (c) special purpose foods intended for a particular group for whom the composition of the diet assumes considerable importance, such as growing infants and children, patients with diabetes, hypertension, and others; and finally (d) new food products of one kind or another classified as novelties or specialties.

When considering the application of new discoveries in the science of nutrition for the improvement of public health, so far as food is concerned, it is evident that the first of the three categories listed is the most important.

The Cereal Grains

Discussions of so-called staple foods (1) that figure prominently in various dietaries throughout the world, are usually in terms of such foods' contributions to the energy needs of the population. The two cheapest sources of food energy in the diets used throughout the world are the cereal grains and cane sugar. In the Orient, notably Southern China, Japan, Burma, Thailand, Assam, Indonesia, the Philippines, and the Madras section of India,

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rice is the most economical, readily available, and, widely used cereal. Such use of rice is not restricted to the Orient, however. For example, it is the staple food on the island of Puerto Rico, as well as in other tropical and near-tropical areas of the Occident. From the standpoint of world-wide use, rice comes first. For an extended discussion of the rice problem in the Orient see earlier issues of this Review (2, 3).

The dominant cereal in the United States is wheat. In certain areas, notably the southern states where pellagra is endemic, corn is a staple cereal. It is also widely used in Rumania, Central America, certain South American countries and Southern Europe.

Man has long known that freshly milled grain does not keep well. It is satisfactory and readily acceptable as a food only if consumed within a short period. If stored, it soon becomes infested with insects, or turns rancid, or both, and thus becomes objectionable as a food for man.

At some time in the distant past it was learned that by milling off the bran and germ part of the brown colored natural rice kernel, a white product could be obtained which had none of these undesirable qualities. It could be transported long distances without spoilage. Its whiteness even gave it a certain "consumer's appeal" which was also an advantage. Such milling came to be regarded in most localities as the proper procedure for preparing the rice for human consumption even if it was to be eaten by people living near where it was produced and did not have to be shipped long distances. It remained for discoveries in the science of nutrition to show that this popular view is in error and actually bad for the public health. The literature concerning this topic may be summed up in the statement that it includes the writings which demonstrated the disease beriberi to be related to the consumption of white rice (4), and that this disorder is a *deficiency disease* (5) due to lack of what is now called vitamin B_1 or thiamine.

Essentially the same parallel can be drawn with respect to the use of wheat in the form of flour. It was soon learned that whole wheat flour does not keep readily for any extended period. By "milling off" more and more of the grain, one obtains a product that consists almost entirely of the white endosperm; the highly refined so-called patent flour represents the "ultimate" end of this process. Products obtained at various stages of the milling are commonly designated 90 percent extraction, 85 percent extraction, etc., according to the fraction of the original grain remaining. Thus, a very highly milled product representing only 70 percent of the original grain would be called a "70 percent extraction flour." This highly milled flour, like white rice, has proven to be better suited for the exigencies of modern civilized life, in that it can be easily transported over long distances, from various milling centers to remote centers of population, without spoilage.

Enrichment of White Flour

The writer (6) pointed out in 1939 that as a result of two factors, the development of the wheat milling industry over a century, as well as the increase in production of sugar to the point where it no longer serves merely as a condiment but actually contributes a significant fraction of the daily calories needed by man, there has been a definite and unmistakable decline in the daily intake of vitamin B_1 — from roughly three to four times the daily minimum to only about one and one-half times the minimum. The desirability of "doing something" about this, counteracting this trend before a condition resembling endemic beriberi should appear in this country, seemed unquestionable. The anti-beriberi vitamin, thiamine, had become available and this fact suggested that it might be in the interest of preventive medicine and public health to add the vitamin to wheat flour, provided that this was technologically feasible.

Also in 1939 there appeared in the United States Public Health Reports the classic paper by Sebrell and Butler (7) showing that vitamin B_2, riboflavin, is essential for human nutrition, and that the incidence of ariboflavinosis (riboflavin deficiency) is sufficiently great, at least in certain areas studied, to warrant consideration of public health measures to combat it. These and related developments came at a time when there was considerable discussion in many quarters of the question of fortification of white flour and other foods with pure vitamins and mineral nutrients like iron and calcium (8). Interest in the possibility of improving the nutritive value of wheat flour increased. Subsequently, much testimony and scientific data were submitted at hearings held by the Food and Drug Administration to set up standards for various types of flour. Out of this finally came standards for what was called *enriched* flour (9). The term *enriched* was selected as the best one to use in describing products of this sort because it was believed to be least open to undesirable interpretations or misleading implications of one kind or another. This point is of considerable importance to a governmental agency charged with the enforcement of such standards. This term has acquired a certain special legal status, which is not the case with other words that have figured in much of the discussion of this general subject, such as *fortified.*

The "definitions and standards of identity for flour and related products" (9) were modified in July 1943 to include those for enriched white flour. To qualify as an *enriched* wheat flour each pound of the flour *must* contain from 2.0 to 2.5 milligrams of thiamine, 1.2 to 1.5 milligrams of riboflavin, 16 to 20 milligrams of niacin, and 13 to 16.5 milligrams of iron. As optional ingredients each pound of the flour may contain from 500 to 625 milligrams

of calcium, 250 to 1,000 U. S. P. units of vitamin D, and wheat germ to the extent of not more than 5 percent by weight of the finished product.

The establishment of standards for enriched flour raised the question whether similar standards should be set up for certain related products, made up very largely of flour, macaroni for example. Hearings were devoted to this question. As a result there finally appeared in 1946 (10) standards for enriched macaroni products and enriched noodle products. These standards specify that each pound contain 4 to 5 milligrams of thiamine, 1.7 to 2.2 milligrams of riboflavin, 25 to 34 milligrams of niacin, and 13 to 16.5 milligrams of iron. The optional ingredients are the same in kind and amount as those specified for enriched white flour (see above). The required additions are greater than the corresponding ones for enriched flour to compensate for the losses which normally occur in cooking macaroni and noodle products.

Following the establishment of Federal standards for enriched white flour in 1941, South Carolina in 1942 passed mandatory state legislation requiring the enrichment of all such products sold in the state. By April 1951 (11), twenty-five other states, as well as Puerto Rico and Hawaii, had adopted similar legislation. The reader interested in the history of this enrichment movement may consult with profit various publications of the National Research Council (12, 13, 14). As has been pointed out by Williams (11), "the movement has had the cordial support of the major part of the milling and baking industries, and the practice of enrichment has been accepted since 1942 or 1943 for three-fourths or more of the total output of white flour and bread. Only small and diminishing fractions remain unenriched."

Enrichment of Corn

The association of a relatively high consumption of corn with a high incidence of pellagra in certain southern areas in the United States stimulated much interest in the possibility of enriching corn products. Because of the fact that in the South corn is milled by numerous small millers instead of a few large operators, it was necessary to devise some simple method that could be readily used by any small miller. This problem was attacked by Dr. E. J. Lease at Clemson Agricultural College in South Carolina. There was finally devised an automatic "feeder" capable of delivering a proper stream of enrichment mixture at the rate required by the capacity of the mill. It was necessary to arrange for the manufacture of this relatively simple apparatus in large numbers. The next problem was to work out the composition of the enriching mixture. This was finally accomplished. Wil-

liams pointed out (11) that it was "necessary to teach the people to ask for enriched meal and at the same time to persuade the millers to pay $25 for a feeder and to buy and use the premix. It has been slow work, but after seven years, 1,000 millers all over South Carolina and Alabama are regularly enriching their corn meal, and the practice is invading other southern states where there is perhaps a total of 6,000 or 7,000 additional small mills."

For the educational work required, as mentioned above, the county agent and the home demonstration agent of the Agricultural Extension Service have given invaluable service in South Carolina and Alabama, this in spite of their many other duties. When the first mandatory enrichment law was passed in South Carolina in 1943, it was made to apply only to degerminated corn meal, a product almost entirely shipped in from the West. The law did not apply to whole corn products of local origin. As a result of the experience gained over a period of about five years, sufficient support finally developed in South Carolina to result in an amendment to the corn enrichment law, effective September 1, 1949, so as to make it applicable to whole corn meal as well as the degerminated products. "The millers and the people now know its merits well enough to give it popular support which is necessary to its enforcement. If it is extended throughout the South and flour and bread enrichment is maintained, pellagra will be an unknown disease to the coming generation" (11).

Standards for the enrichment of meal and of corn grits were finally established in 1947 (15). Enriched corn meal and enriched corn grits must contain per pound, not less than 2.0 to 3.0 milligrams of thiamine, 1.2 to 1.8 milligrams of riboflavin, 16 to 24 milligrams of niacin and 13 to 26 milligrams of iron. As optional ingredients there may be added per pound of the product from 250 to 1,000 U. S. P. units of vitamin D, 500 to 750 milligrams of calcium, and dried yeast to the extent of not more than 1.5 percent by weight of finished product.

Enrichment of Rice

In earlier issues of this Review one finds discussions of the problem of rice eating populations in the Orient (2), and the so-called "Philippine Experiment" (3) which consisted essentially of a field trial of an enriched white rice in the province of Bataan, Philippine Islands.

In the United States rice is not a staple food eaten by most of the citizens. It is eaten in appreciable amounts in Louisiana and Arkansas and the coastal areas of some other southern states. For this reason it has not seemed justified to prosecute any national program calling for the enrichment of rice. The importance of the problem for so many other parts of the world, however, is such that the Food and Nutrition Board of the National Research Council

authorized and published in 1945 a study of the "Nutritional Improvement of White Rice" (16), with especial reference to the rice industry in the United States.

Among the various commercial possibilities presenting themselves, that based on the ancient practice in India of parboiling rice seemed most promising. It has been estimated that parboiling applies to about two-thirds of the rice used in India. The process is very simple. It consists, traditionally, of steeping the rough rice (paddy) in hot water for some hours, drying it in the sun, and then shelling and milling it in the usual way. It is likely that it was done originally to loosen the hulls. However, modern research has revealed that as a result of the parboiling, the vitamins and minerals in the bran coats and the germ are dissolved in considerable measure and transferred in part to the inner white endosperm, thus enrching the milled product. The United States commercial process of "converting" rice is a modernized version of this parboiling process. It is of course evident to all students of nutrition that this process would also inactivate enzymes involved in rancidity changes and therefore the resulting product should be capable of longer storage without spoilage than is the case with the natural brown rice. Parboiling has been shown to produce some change in flavor, but this altered flavor is widely accepted in those areas of India where parboiling is commonly employed. Trials of it in the Philippines, Puerto Rico and Cuba (11), however, have not met with favor.

In the Bataan Experiment (3), since a parboiled product was not acceptable, a rice enriched by a different process was used, that devised by Furter and associates (17). A premix is prepared which can be fed into a stream of white rice by means of a suitable apparatus, essentially the same process as was mentioned above in discussing the enrichment of corn products. In preparing the premix by the Furter, *et al* process, rice is wet with a mixture of thiamine, niacin and iron in water solution, then dried and coated with a film of zein from alcoholic solution. The dried product may be so highly fortified that one pound of it mixed with 200 pounds of rice will bring the levels of the added ingredients up to those of brown rice. The zein film prevents the loss of vitamins when the rice is rinsed but is digested when the rice is eaten. This fortified rice cannot be distinguished from white rice either raw or cooked. It will be noticed that riboflavin is not used in this premix. This is because riboflavin contributes a yellow color, and it was feared that the housewife would pick out the colored particles and discard them, thinking they were spoiled grains. In other respects, this rice meets the levels required in the United States for enriched white flour and enriched corn meal, namely minima per pound of 2.0 milligrams of thiamine, 15 milligrams of niacin and 13 milligrams of iron.

Recent publications show that the enrichment of rice is being studied in other countries where rice is a staple food. Simpson (18), in the Institute of Medical Research, Kuala Lumpur, Federated Malay States, reports on the distribution of thiamine and riboflavin that occurs in rice grains during the parboiling process. In Japan, Kondo and associates (19) at the Research Institute of Food Science, Kyoto University, recently studied the parboiling process in further detail, and finally offered a method of enrichment that might be called "acid-parboiling." It involves, prior to the parboiling, a soaking of the brown rice in a 1 percent acetic acid solution of thiamine-HCL. This preliminary acid treatment is reported to improve the penetration of the vitamin into the endosperm during the parboiling. It also is said to make the outer layer of the rice kernel more firm in texture, thus affording greater resistance to bacterial deterioration. It is claimed that this enriched rice does not suffer from insect attack.

Principles Governing Enrichment or Fortification

Discussion of enrichment or fortification of foods has brought out many suggestions of principles and facts to be considered when adding vitamins and minerals to foods. Is the ordinary diet sufficiently deficient in the dietary essential in question to justify the proposed addition of it to appropriate foods? If no real need for such addition is shown, one may question the wisdom of it as a socially planned and directed move; its chief justification then becomes a commercial one dependent for its success almost entirely on advertising and promotional activities. It is of course quite appropriate for the food industry to experiment in the development of new fortified or "enriched" products, but it is also the responsibility of the nutritionist, public health workers and governmental authorities to see that these developments are based on sound nutritional practices and not designed simply as a means of "selling more of the product." It is indeed encouraging that a large segment of the food industry takes this enlightened point of view. As of this date, the following fortified or "enriched" products have received official recognition in accordance with these principles: (a) enriched white flour, (b) vitamin D milk, (c) iodized table salt, and (d) vitaminized margarines. What other products will attain this status in the future only time and further research can determine.

What is to be considered an appropriate food to which dietary essentials might well be added? White flour, white rice and corn meal, and certain related products, are now considered as qualifying in this respect. Even if a given class of foods is to be considered as suitable, it does not automatically follow that all members of the class can be so regarded. One must consider how each one is normally eaten. If it is nearly always cooked and thereby

loses too much of the vitamin, it may not be a suitable vehicle for fortification. From this it is evident that a substantial body of facts regarding individual foods, the stability of vitamins in them under various conditions, and related points, is needed in order to answer this question satisfactorily.

These principles have been discussed in published statements of (a) the Council on Foods and Nutrition, of the American Medical Association in 1939 and 1946 (20), (b) the Committee on Food and Nutrition (now Board) of the National Research Council in 1941 (21), and (c) the federal government in 1943 (22).

In much of the discussion of this subject the term "restoration" has been used. By it is meant the addition of a nutritive ingredient to a processed food in amount sufficient to *restore* to the normal level what was unavoidably lost during the processing. While this term is useful in this limited area, it does not cover as broad a field as the terms *enrichment* and *fortification.*

Other Methods of Improving Foods

The artificial addition of specific nutrients to foods is not the only method available to us for improving foods. One may select plant varieties on the basis of genetic constitution and vitamin content. Varieties of wheat and other cereals differ considerably in their respective contents of thiamine (23). For example, thiamine contents per pound of five varieties of wheat (Durum, Hard Spring, Hard Winter, Pacific and Soft Red) range from 1.45 to 3.80 milligrams; comparable ranges for oats, barley, corn, rye, respectively, are 2.20 to 4.90 milligrams, 2.58 to 3.33 milligrams, 1.85 to 3.04 milligrams, and 1.88 to 2.28 milligrams. It is evident that there is no such thing as a standard "whole wheat flour" with respect to "high natural level" of thiamine content.

In the case of corn, its content of niacin is of considerable interest. Burkholder, *et al* (24), assayed 45 strains of sweet corn, 94 of yellow corn, 86 of white corn, and 7 of popcorn. As an example of the range, consider the figures for sweet corn which ran from 1.82 to 6.21 milligrams of niacin per 100 grams of the corn.

In their earlier work on this problem reported in 1948, Richey and Dawson (25) studied 24 inbreds of white dent corn and obtained a range of niacin content of 1.39 to 5.33 mg. per 100 gm. They stated: "It is concluded that corn hybrids with niacin concentrations as high as 50 micrograms per gram could be developed." A 1951 paper by these same workers reported the conclusion that niacin concentration in corn is a function of the genetic constitution of the endosperm with practically no influence by kernel size, environment, or by differences in the physiology of the seed-parent plants

as between starchy and sweet plants. They mention the fact that one selected ear of the 1949 crop had a concentration of 91.8 micrograms per gram.

The now well-known interrelationship in nutrition of niacin with the amino acid tryptophan has led to similar genetic studies of corn with particular reference to the inheritance of proteins, zein for example, and various amino acids now known to be essential for man. Doty, *et al* in 1946 (26) concluded that "the amounts of certain amino acids in corn proteins are affected, to some extent at least, by the genetic constitution of the plant." From the 1951 report of Frey (27), it appears that with the particular plant samples he examined (F_2 generation and backcrosses of two maize crosses), zein was produced in increasing proportion as the total protein percentage increased; this resulted in a decrease in percentage of the amino acid tryptophan. It seems evident that this problem of the improvement of the protein in corn by experiments in genetics is complicated and will require much more research.

The study of Porter and associates (28) is somewhat different from those just cited in that it relates to the entire corn plant and its value for making silage for cattle. These workers studied the carotene content of the corn plant. They found that significant differences between stocks, both inbred and hybrids, exist but are relatively small. The sun-red gene had no influence. This study is a contribution to the question of how to increase the carotene content of silage fed to dairy cattle and thus to affect the vitamin A potency of cow's milk.

Progress in this field of research must necessarily be slow because the experimenter usually gets only one crop per year and generally seven or eight years are required for purification and standardization of any new hybrid. Another factor is important here relating to other non-nutritive characteristics of the plant food, such as texture and resistance to disease, that determine its commercial processing value. Some hybrids may be more valuable from the nutritive standpoint but inferior for one or more non-nutritive reasons. In such cases considerable further work is obviously needed in order finally to secure hybrids that have the most desirable combinations of all factors, nutritive and non-nutritive. An over-all account of the problems and developments in this field will be found in the paper by Garber (29).

Genetic constitution has also been studied in relation to the ascorbic acid content of cabbage (30). According to Walker and Foster, "the high ascorbic acid character was apparently well fixed and resulted in intermediate levels in the F_1 from crosses with low acid lines. . . . That fairly high ascorbic acid content can be combined with high yield and increased resistance has already been indicated." Smith and Walker (30) wrote: "We may expect,

therefore, to see the development and adoption of cabbage varieties greatly improved in nutritive value, disease resistance, and productivity."

The sweet potato has been studied with the view to developing varieties with higher contents of carotene and ascorbic acid. Elmer (31) at Kansas State College has used the method of mutation in his work. Miller at the Louisiana Agricultural Experiment Station has made genetic crosses and as a result has obtained varieties even higher in carotene content, and with enhanced palatability (31).

Some staple foods can be nutritively improved by special methods of cultivation. The literature on the effects of soil character, exposure to sunlight, supply of special materials to the soil, water supply, and similar factors is very extensive and cannot be cited here. Let it suffice to mention two suggestive items of interesting information. The amount of ascorbic acid in the tomato is markedly influenced by the amount of exposure of the fruit to sunlight shortly before harvesting (32). The amount of iodine in the potato has been found to reflect the iodine concentration in the soil and water (33).

Nutritive improvement of foods of animal origin, such as milk and its derivatives, can be obtained in accordance with the principles outlined above. Since milk as ordinarily marketed is such an excellent food, the question of any need for its improvement has aroused debate. Its value as a means of increasing the intake of vitamin D by infants and children in order to combat rickets is now generally conceded. Studies have been made to determine whether the vitamin A content of milk can be significantly increased by administering the vitamin to the cow. The experiments of Deuel and associates (34), which involved the feeding of extremely concentrated preparations, indicate that the metabolic transfer of vitamin A through the mammary gland is not economical. Improved feeding of cows during the winter season when they are not on pasture (28) is another approach to this problem. At least one branch of the dairy industry has brought out a vitamin and mineral fortified fluid milk, one quart of which furnishes the daily requirements of various vitamins and minerals, except vitamin C, for which official Federal standards for use in checking label statements have been established. A number of states now officially recognize such a product through their own established regulations.

The objective in this case is a high quality fluid milk in which important naturally occurring vitamin and mineral nutrients are increased by fortification to higher levels and balanced to meet recognized human requirements. Some of these important nutrients are present in small or variable amounts in regular milk. It is a special milk which affords a means of supplementing the diet, when indicated, with a basic food in combination with the recognized nutritive merit of milk.

Many authorities would like to see more skim milk used as a food by man. Its high-protein, mineral-rich, low-fat characteristics make it a valuable food for various dietary purposes. Students of milk markets report that some improvement in flavor is needed in order to secure greater acceptance of it. It has been amply demonstrated that the flavor can be improved by the addition of small amounts of non-fat milk solids, so that the resulting product is judged by the consumer to be actually superior to ordinary skim milk. Since skim milk contains little or no vitamins A and D, it has been suggested that they might be added. Such products are now available in most areas. Similar considerations seem to apply to powdered skim milk. Other milk products that have received attention are the result of special processing, evaporated canned milk for example. To the extent that any of them may suffer a vitamin loss by the processing which cannot be corrected by changing the processing method, they might be improved by using the principle of restoration of the vitamins in question to "high natural levels," as contrasted with fortification in order to obtain a product intended for some special use.

In conclusion, it seems evident that regardless of what may be done to improve the nutritive value of foods, whether along lines urged by public health authorities or through frank experimentation by units of the food industry, there remains the need for continued effort to educate the general public regarding the basic food needs and how they may be met by appropriate choices of foods; in other words, the development of good food habits. Any improvements that are made in the various foods among which these choices are to operate amount to improvements in the food environment of the people. The greatest effects here will obviously come from improvement of the cheap staple foods, those that are used in largest amounts by the mass of the people, particularly those with low incomes, who have the least to spend, and who therefore are in greatest need of assistance in the improvement of their food environment.

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